PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

The Effects of Ventilation Filters on Indoor Air Quality in California Classrooms

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Contractor: Lawrence Berkeley National Laboratory
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Are HVAC filters degrading indoor air quality? Ozone has been shown to react with the particles and aerosols adsorbed by the filters—generating formaldehyde, a persistent air quality problem in California classrooms.

The Issue

In addition to providing heating, ventilation, and air conditioning, most HVAC systems use filters to remove dust and other particles from the air. Such filtration is generally expected to improve indoor air quality. However, the particulate matter and sorbed chemicals that collect on the surface of HVAC filters are subject to further chemical reactions, which can result in secondary pollutants that may have worse health effects than the original substances collected on the filter.

For example, HVAC filters are highly susceptible to chemical attack by ozone, a reactive chemical present in urban smog. These filters are the first major surface where outdoor ozone can react during its transit into the indoor environment. The ozone concentration at the HVAC intake is close to its outdoor value, i.e., considerably higher than the indoor ozone concentration. Prior research has documented the capture of ozone as air flows through filters. While HVAC systems are operating, dust and other particles are continually being deposited on their filters, providing fresh supplies of material with a large effective surface area for reacting with ozone or other chemicals.

Older filters, heavily laden with particles, have been associated with health symptoms, degraded perceived air quality, and reduced work performance. The combination of these factors may constitute a significant source of indoor secondary pollutants and aerosol particles. A European study performed in a primary school revealed that when ventilation filters were removed from the supply air duct, perceived air quality improved significantly.[1] A recent literature survey

[1] Mysen M, Fostervold KI, Schild PG. An intervention study of the impact of supply air filters on perceived air quality and health symptoms in a primary school. *Proceedings of Healthy Buildings 2006 Conference*. Lisbon,

found evidence suggesting that poor indoor air quality in schools is common and adversely influences student performance and attendance, primarily due to health effects of indoor pollutants.[2]

More specifically, studies indicate a link between ozone chemistry on HVAC filters and the formation of formaldehyde—a ubiquitous indoor pollutant that the World Health Organization recently reclassified as a known human carcinogen.[3] In a recent study of 100 office buildings, researchers from Lawrence Berkeley National Laboratory observed a significant correlation between levels of outdoor ozone and indoor formaldehyde concentrations.[4] Another report indicated that up to 11% of the ozone removed by HVAC filters generates formaldehyde.[5]

The health impact could be significant: In a recent study performed in portable classrooms in California, formaldehyde was the only volatile organic compound consistently exceeding its chronic reference exposure levels (CREL, 3 $\mu g/m^3$).[6]

Project Description

This PIER project, funded by the Environmental Exploratory Grants Program, seeks to better understand the potential for indoor air quality (IAQ) degradation in California classrooms due to ozone reactions in ventilation filters—and to assess the need for follow-up research.

The project will conduct a lab-bench experiment in which sections of HVAC filters obtained from California schools will be exposed to atmospheres under controlled airflow, ozone concentration, relative humidity, and temperature conditions. A flow tube apparatus will be used to identify the key constituents of HVAC filters that react with ozone and to quantify the formation of volatile indoor pollutants and secondary organic aerosols. Under realistic operating conditions, ozone consumption and the corresponding yield of formaldehyde and other airborne pollutants will be explored. Extraction, chemical analysis, and infrared surface spectroscopy will be employed to identify the main chemical transformations taking place on the exposed surfaces.

Experimental results will serve as a basis for evaluating the overall impact of ozone reactions at HVAC filters in California classrooms. The study will estimate the indoor pollutant concentrations generated in ozone reactions at HVAC filters and compare the predicted concentrations to values found in typical indoor classroom environments. Estimates will be provided for different scenarios based on the minimum, average, and worst-case values measured in the experiments. This analysis will allow preliminary assessment of the relative contribution of HVAC filter reactions to overall indoor pollutant levels.

Portugal, June 2006. Eds. Oliveira Fernandes E, Gameiro da Silva M, Rosado Pinto J. Univ. de Porto, Vol. III, 213-216.

[2] Mendell MJ, Heath GA. Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air* 2005, 15, 27-52.

[3] Cogliano VJ, Grosse Y, Baan RA, Straif K, Secretan MB, El Ghissassi F. Meeting Report: Summary of IARC monographs on formaldehyde, 2-butoxyethanol and 1-tert-butoxy-2-propanol. *Environ. Health Perspectives* 2005, 113, 1205-1208.

[4] Michael G. Apte, Lawrence Berkeley National Laboratory, MGApte@lbl.gov.

[5] Hyttinen M, Pasanen P, Kalliokoski P. (2006). Removal of ozone on clean, dusty and sooty supply air filters. *Atmos. Environ*. 40, 315-325.

[6] Hodgson AT, Shendell DG, Fisk WJ, Apte MG. Comparison of predicted and derived measures of volatile organic compounds inside four new relocatable classrooms. *Indoor Air* 2004, 14, 135-144.

This study will help define future research directions, which may involve:

- The effect of school location, which impacts the nature and amount of particles deposited on filters and the level of outdoor ozone.
- The effect of filter media on the ozone reactions with sorbed or deposited chemicals—either through direct reaction with ozone (likely in the case of synthetic polymeric filters), or through indirect interactions with the filter matrix.
- Air quality surveys in California classrooms, including environmental measurements and questionnaires to evaluate perceived air quality.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Evaluating and resolving the environmental effects of energy use.** By assessing the extent to which filter systems may be degrading IAQ, this project takes a first step toward addressing a potentially widespread public health effect from HVAC equipment.
- **Providing environmentally sound, safe, and affordable energy.** If, as expected, a significant problem is identified, subsequent studies will be designed to identify energy-efficient solutions that improve classroom IAQ and student health and performance. Some of the anticipated solutions would save energy—and cut electric bills—while improving IAQ.

Final Report

PIER-EA staff intend to post the final report on the Energy Commission website in fall 2008 and will list the website link here.

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